U.S. Coast Guard Research and Development Center
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BALLAST WATER TREATMENT STANDARDS

EAST COAST AND WEST COAST WORKSHOP SUMMARIES

Final Report
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16. Abstract (MAXIMUM 200 WORDS)

In response to the pressing need for a quantitative standard by which ballast water treatment technologies can be evaluated, the U.S. Coast Guard Research and Development Center conducted two workshops. The purpose of the workshops was twofold: 1) to obtain expert technical opinion on approaches to setting and implementing standards for ballast water discharge; and 2) to develop potential standards and protocols for approving ballast water treatment. Results from the workshops will provide the scientific, regulatory, and engineering bases by which the Coast Guard may establish an effective, measurable ballast water treatment standard. Participants in the first workshop developed long- and short-term standards for three functional groups of organisms. Participants in the second workshop developed one long- and one short-term standard aimed at reducing the threat from all organisms. The majority of participants recommended that the standard be scientifically based and independent of the capacity of the receiving system, effectiveness of ballast water exchange, or best available technology. Recommendations for the development of protocols included testing under a range of environmental conditions at laboratory and shipboard scales, and testing to determine operation and maintenance constraints. Research required to support standards included: 1) biology of ballast tanks; 2) risk/likelihood of invasion; 3) identification indicator species and surrogates; 4) efficacy of treatment technologies; and 5) methodologies and protocols for testing.

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ballast water standards, protocols, workshop, U.S. Coast Guard, ballast water treatment

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EXECUTIVE SUMMARY

Successful invasions of nonindigenous aquatic nuisance species (ANS) have been increasing at an alarming rate over the last several decades with significant adverse impacts on the economies, human health and ecosystems of affected areas. The costs of these nuisance species to local economies, and effects on native species have been considerable. One of the primary vectors for the movement and unintentional dispersal of aquatic organisms within and between oceans is ballast water.

In an effort to address the problem, Congress enacted the National Invasive Species Act of 1996 (NISA) (Pub. L. 104-332), which provides for ballast water management practices, including ballast water exchange and ballast water treatment to prevent introductions and spread of ANS. Under NISA, the voluntary ballast water management practices recommended by the U.S. Coast Guard (USCG) become mandatory after three years if the Secretary of Transportation determines the voluntary use of the program to be ineffective for preventing biological introductions. Specifically, the mandatory program would require vessels operating outside the two hundred mile exclusive economic zone (EEZ) to conduct an open ocean ballast water exchange or to effectively treat the ballast water before discharging into U.S. waters. As directed by Congress, the USCG is presently conducting a survey to determine the rate of compliance with the voluntary ballast management guidelines. However, given that ballast exchange is not practicable on all voyages, nor is it likely to be effective on coastal voyages, there is a high probability that ballast water treatment may be required in the future. Industry has responded to this anticipated need by developing various kinds of treatment technologies, at varying degrees of effectiveness.

A key hurdle to developing accepted ballast water treatment technologies is the absence of a standard by which proposed technologies can be evaluated. As a proactive measure, the USCG Research and Development Center (RDC) determined that expert technical opinion on approaches to setting and implementing quantitative standards for ballast water treatment should be obtained. RDC conducted two workshops that brought together technical expertise in the field of ballast water treatment, invasion biology, and standards development. The first panel of experts, representing the East Coast and Great Lakes was convened at a workshop in Mystic, CT. The second panel, representing the West Coast and Gulf Coast was convened in Oakland, CA.

The primary objectives of the workshops were to develop standards and protocols for approving ballast water treatment methods. Participants at each workshop were asked to address three primary issues to assist in developing standard statements:

- Is it possible to develop a biological standard for ballast water treatment technologies and if so, what might be the necessary attributes of the standard(s)?
- What research is needed to support the development of standards and further the treatment development process?
- What design elements and protocols are necessary to incorporate in the ballast water treatment approval tests?

In addressing these issues, the participants were asked to strive for achieving consensus; consensus being defined as “I can live with the decisions we have made when I leave this workshop.” This report summarizes the discussions, resulting conclusions, recommendations and specific consensus achieved by the two workshops.

During both workshops, the participants discussed and addressed many complex and interrelated issues, raised questions, voiced concerns and identified areas demanding more research. Issues discussed included:

- the current level of knowledge and the predictability of invasions;
- the most effective approach to reducing invasion risk;
- the most effective type standard to implement (i.e., management, performance, or process);
- the level of protection the standard should provide;
- and the scientific basis of, and the quantitative measure for, the standard (i.e., biological or other type of indicator, relative vs. absolute).

Participants in both workshops struggled with developing standards because the current knowledge of invasion predictability was considered very limited. They determined that much research is still needed to assess the predictability issues. Therefore, the participants in both workshops debated the level of protection the standard could and should provide as well as quantitative measures of the standard. In spite of initial skepticism regarding the ability to develop meaningful standards, the discussions during both workshops led to a clear conclusion that it is possible to develop a biological standard for treatment technologies. The considerations demonstrated, however, that substantial research would be required to develop and support any standard. Because of the uncertainties in our present knowledge regarding the issue, participants were challenged to develop statements for both short-and long-term standards. Through continued debate, both workshops were able to develop standards statements. Each workshop was also able to achieve consensus on short-term standards that could be adopted and which could immediately begin to reduce the risk of invasion. Each workshop supported a goal of achieving 100 percent protection against invasions in the long-term and was able to reach consensus on statements of long-term standards.

The East Coast workshop participants drafted three short-term standards and three long-term standards that are based on three different functional groups identified during their discussions: 1) holoplankton, meroplankton, demersals; 2) the photosynthesizers which consist of phytoplankton, cysts, and algal propagules; and 3) bacteria and viruses (including pathogens). These short-term standards are:

- 99 percent of all coastal holoplankton, meroplankton, and demersals, and their respective life stages should be removed.
- 95 percent of all phytoplankton, cysts, and algal propagules and their respective life stages should be removed or rendered inactive.
- *Enteroccoci* in ballast water discharge should not exceed 35/100mL or *E. coli* should not exceed 126/100mL.

The long-term standards recommended by the East Coast participants were similar for two of the three functional groups (i.e., coastal holoplankton, meroplankton, demersals group and the photosynthesizer functional group). Specifically, participants recommended all organisms and respective life stages in both groups be removed or rendered inactive. The long-term standard for the bacteria/virus/pathogen functional group was identical to the short-term standard.

Participants in the West Coast workshop drafted one short-term standard and one long-term standard. Consensus was achieved on the following short-term standard:

> Discharge should not include organisms greater than 50 μm and should be treated to meet federal criteria for contact recreation (35 Enterococci/100 mL for marine waters and 126 E. coli/100 mL for freshwater).

The West Coast participants agreed that the long-term standard should be zero discharge of all organisms.

Participants considered the viability of the treatment standard frameworks identified in November 2000 by the Ballast Water Shipping Committee (BWSC). These included the following options as the basis of a ballast water treatment standard.

- Theoretical effectiveness of ballast water exchange in replacing water (i.e., 95 percent)
- Measured effectiveness of ballast water exchange in the removal of organisms
- Measured capabilities of best available technology

Participants also considered the appropriateness of basing the standard on the capacity of the receiving system, an option that also has been considered by the BWSC.

The workshop discussions clearly indicated that standards based on comparisons to either theoretical or measured effectiveness of ballast water exchange were not advisable. This conclusion was based on the participants' collective opinion that the current knowledge base on the efficacy of exchange is insufficient relative to biological removal/inactivation to provide a comparative basis for the standard. The workshops indicated that research in this area was a priority. The East Coast participants suggested that BWE might be viewed best as a treatment alternative.

The pros and cons of best available technologies (BAT) were also considered. Consensus on the validity of using this approach as the basis for developing the standard was not achieved. The expert opinions on this approach can be summarized as:

- Standards should be based on a measure that is scientifically designed to protect the resource, as opposed to what is achievable with current technology.
- Using a BAT approach may thwart the development of new technologies because it removes the incentive for vendors to achieve more stringent treatment goals.
- BAT approach could be used as an interim approach to setting a standard but should be replaced by a scientifically and biologically based standard in the future.
- BAT is a valid approach to setting the standard because it facilitates a practical and achievable target; setting a standard on a measure that is not currently achievable will not be effective.

Participants in both workshops also agreed that basing the standard on the capacity of the receiving system was not advisable, as there is currently not enough knowledge to determine what the capacity of the receiving ecosystems might be relative to invasions. It was voiced that this type of approach would more likely provide for the adoption and implementation of regional standards. Both workshops agreed that a national standard was more desirable than regional standards.

The protocols for approving treatment methods received considerable discussion. Because these discussions were linked to specifications of the standard and uncertainties in our knowledge base, specific protocols for verification testing of treatment technology against ballast water standard(s) could not be developed. However, key issues that any protocol used for standards verification or certification must address were identified. These included testing at various scales (laboratory and shipboard), testing under a range of environmental conditions, use of surrogates, use of natural indicators, operation and maintenance constraints, and methods for sampling and measuring organism viability in ballast tanks.

The participants also identified areas requiring additional research that would aid in the development of a ballast water treatment standard. Many participants reiterated that although there has been much recent research and attention focused on the issues of invasion biology, there are still many unknowns in the field, particularly with respect to ballast water. The areas of required research identified by the participants can be categorized into five groups including: 1) biology of ballast tanks; 2) risk/likelihood of invasion; 3) identification indicator species, surrogates or both; 4) efficacy of treatment technologies; and 5) methodologies and protocols for testing.

Results from these workshops will provide the scientific, regulatory, and engineering bases by which the USCG may establish an effective, measurable ballast water treatment standard.

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LIST OF ACRONYMS

ANS	Aquatic Nuisance Species
ATP	Adenosine Triphosphate
BAT	Best Available Technologies
BWE	Ballast Water Exchange
BWSC	Ballast Water Shipping Committee
CKBS	Collaborative Knowledge-Based Solutions
cm	centimeter
CT	Concentration and Time
EEZ	Exclusive Economic Zone
μm	Micrometer
mL	Milliliter
NISA	National Invasive Species Act
NPDES	National Pollutant Discharge Elimination System
PC	Personal Computer
SERC	Smithsonian Environmental Research Center
USCG	United States Coast Guard
USCG RDC	United States Coast Guard Research and Development Center
USEPA	United States Environmental Protection Agency

1.0 INTRODUCTION

1.1 Background

Successful invasions of nonindigenous aquatic nuisance species (ANS) have been increasing at an alarming rate over the last several decades with significant adverse impacts on the economies, human health and ecosystems of affected areas. The costs of these nuisance species to local economies, and effects on native species have been considerable. One of the primary vectors for the movement and unintentional dispersal of aquatic organisms within and between oceans is ballast water.

In an effort to address the problem, Congress enacted the National Invasive Species Act of 1996 (NISA) (Pub. L. 104-332), which provides for ballast water management practices, including ballast water exchange and ballast water treatment to prevent introductions and spread of ANS. Under NISA, the voluntary ballast water management practices recommended by the U.S. Coast Guard (USCG) become mandatory after three years if the Secretary of Transportation determines the voluntary use of the program to be ineffective for preventing biological introductions. Specifically, the mandatory program would require vessels operating outside the two hundred mile exclusive economic zone (EEZ) to conduct an open ocean ballast water exchange or to effectively treat the ballast water before discharging into U.S. waters. As directed by Congress, the USCG is presently conducting a survey to determine the rate of compliance with the voluntary ballast management guidelines. However, given that ballast exchange is not practicable on all voyages, nor is it likely to be effective on coastal voyages, there is a high probability that ballast water treatment may be required in the future. Industry has responded to this anticipated need by developing various kinds of treatment technologies, at varying degrees of effectiveness.

A key hurdle to developing accepted ballast water treatment technologies is the absence of a standard by which proposed technologies can be evaluated. In anticipation of the potential future need to regulate ballast water discharges, the USCG Research and Development Center (RDC) determined that expert technical opinion on optional approaches to setting and implementing quantitative standards for treated ballast water should be obtained.

Two important issues will influence the development of standards for ballast water discharge. First, under the current national program guided by NISA, Congress directed that alternative practices be as effective as ballast water exchange (BWE) in preventing invasions. A limited but growing number of rigorous studies have experimentally investigated the effectiveness of exchange. The results of these studies are variable, particularly with regard to the expulsion of coastal organisms from ballast tanks. Given the questionable effectiveness of exchange, the narrative criterion "as effective as ballast water" fails to provide adequate guidance for developing acceptable treatment technologies.

In addition, BWE has several drawbacks that compromise its utility as a basic management practice. Under rough sea conditions, vessels may not be able to carry out exchange safely. In situations where exchange is possible, the water and organisms in many tanks cannot be entirely removed for a variety of reasons. Additionally, mid-ocean exchange is not possible on voyages restricted by route to coastal areas and is not useful in reducing the ballast water mediated spread of organisms along coasts. Similarly, exchange is not possible on some routes within the Gulf of Mexico without transit delays or detours.

Second, a host of alternative treatment approaches have been brought to various stages of development during the last few years. The emergence of these technologies has prompted the need for a technical standard by which their efficiency can be evaluated and treatments certified. The USCG would be responsible for certifying the treatment methods. Moreover, certification requires that ballast water treatment standards, and the protocols for evaluating whether the standard is met, be available. To obtain information and opinions regarding potential ballast water treatment standards, the USCG RDC decided to conduct two workshops that brought together technical expertise in the field of ballast water treatment, invasion biology and standards development. One workshop was held on the East Coast (Mystic, CT) in April 2001, and a second workshop was held on the West Coast (Oakland, CA) in May 2001.

1.2 Workshop Objectives

The objectives of these workshops were to obtain information and, if possible, develop standards statements and to identify protocols for approving ballast water treatment methods. Both workshops were intended to be an early "first" step in the process of developing standards for the treatment of ballast water to reduce the probability of introducing nonindigenous species into the waters of the United States.

It was recognized during the planning for the workshops that defining a specific standard or set of standards may not be immediately possible, especially given the paucity of available data on the effectiveness of exchange or current technologies for treating ballast water. Therefore, participants were asked additionally to identify and prioritize necessary research that might be required for a standard(s). The professional recommendations of the participants regarding funding estimates and timelines for the research effort were also sought.

Prior to each workshop, participants were given a briefing package containing a suite of background information on aquatic nuisance species and ballast water issues, as well as information pertaining to standards development. The contents of the briefing package are listed in Appendix A. The participants were asked to review key papers from the briefing package to prepare for active participation in the workshops.

To meet the workshop objectives, participants were asked to:

- Evaluate biological, environmental, and engineering parameters and issues essential to developing the standard by defining the key attributes or qualities that would characterize the standard;
- Develop potential quantitative criteria of the standard;
- Recommend protocols for evaluating various types of treatment methods; and
- Identify and prioritize the information and areas of research necessary to set the standard.

The participants were also asked to consider the potential for development of short-term and long-term goals for the standard, recognizing that, at least initially (i.e., short-term), the maximum achievable level may provide a significantly lower level of protection than a long-term goal.

Four frameworks for developing the standard(s), recommended by the Ballast Water and Shipping Committee (BWSC) in November 2000, were provided to the participants for consideration. Participants were asked to determine each framework's usefulness as the "benchmark" for treatment effectiveness in the event that ballast water exchange is no longer used. These options included:

- A standard based on the theoretical effectiveness of ballast water exchange in replacing water
- A standard equivalent to the measured effectiveness of ballast water exchange
- A standard based on the measured capabilities of the best available technology
- A standard based on the biological requirements (capacity), as empirically estimated or modeled, of receiving systems

This report summarizes the results of both the East Coast and West Coast Ballast Water Treatment Standards Workshops. The logistics of the workshops and brief profiles of the participants are presented in Section 2.0. A daily overview and synthesis of the discussions that occurred during the East Coast workshop is presented in Section 3.0. A daily overview and synthesis of discussions that occurred during the West Coast workshop is presented in Section 4.0. The conclusions and recommendations from both the East Coast and West Coast workshops, including issues the participants reached consensus on, unresolved issues and future research needs, are presented in Section 5.0.

2.0 WORKSHOP CONDUCT

2.1 Logistics

The East Coast Ballast Water Treatment and Standards Workshop was held April 17 – 19, 2001 at the AmeriSuites Hotel in Mystic, Connecticut. The West Coast workshop was held the following month (May 23-25, 2001) at the Best Western on the Square in Oakland, California. For both workshops, a select group of scientists and engineers from various academic institutions and research facilities were invited to participate in the discussions. Both the scientists and engineers had varying perspectives and levels of experience relating to ballast water issues. The USCG RDC intentionally diversified the levels of issue-specific knowledge and type of experience to foster group dynamics that would adequately explore and address the concepts of standards development for ballast water. Brief profiles of the East Coast and West Coast participants are presented in Sections 2.2 and 2.3, respectively. The contact information for each of the participants is included as Appendix B. In addition to the scientists and engineers who actively participated in the discussions, several members of the Coast Guard, members of Battelle/George Sharp Inc., a U. S. Environmental Protection Agency (USEPA) representative, and an individual from NSF International, were also present to observe the discussions. The list of observers is also included in Appendix B.

The workshops used a unique approach to record the technical exchange and recommendations of the participants. The approach combined traditional facilitation aided by computer-based Groupware technology. Staff from Battelle and George Sharp Inc. assisted the overall workshop facilitator in managing deliberations, responding/clarifying issues and documenting discussions. The facilitation and documentation of the workshop sessions were enhanced using the Collaborative Knowledge-Based Solutions (CKBS) Groupware, a PC-based software package. This software system increased participation and provided a written information repository to capture group discussions and recommendations. Prior to the workshop, the Groupware was structured around the session topics so that deliberations could be recorded. The participants first provided written feedback to session topic questions by typing into their individual PC stations. “On-line” discussions then took place as participants typed responses to each other’s comments. Use of the Groupware system allowed the facilitator to concentrate on the technical progress of the session knowing that discussions and opinions were captured electronically.

The original workshop agenda containing specific topic areas and questions pertaining to those topics was used to structure the Groupware system. The West Coast workshop agenda was somewhat modified based on discussions from the East Coast Workshop.

2.2 East Coast Workshop Participants

This section briefly summarizes the expertise of the East Coast workshop participants. The contact information for these individuals is included in Appendix B.

Don Anderson. Dr. Anderson is with the Biology Department at Woods Hole Oceanographic Institution. Dr. Anderson’s background is in phytoplankton ecology. His expertise includes research on red tides, harmful algal blooms and dinoflagellate cyst ecology.

Ernest Blatchley. Dr. Blatchley is with the School of Civil Engineering at Purdue University. Dr. Blatchley's background is in environmental engineering with an emphasis on the processes applied to the treatment of water, particularly the disinfection process.

Allegra Cangelosi. Ms. Cangelosi is with the Northeast-Midwest Institute. Ms. Cangelosi has a background in environmental science with twelve years of experience in ballast water issues including six years of ballast water treatment testing.

Brian Howes. Dr. Howes is with the Coastal Systems Program, School of Marine Science and Technology at the University of Massachusetts, Dartmouth. Dr. Howes is an estuarine ecologist and biochemist currently working on a USCG RDC project auditing ballast water treatment alternatives.

Junko Kazumi. Dr. Kazumi is a microbiologist with the University of Miami. Dr. Kazumi's background is in coastal oceanography, and she is currently working on a USCG RDC project testing ballast water treatment technologies.

Whitman Miller. Dr. Miller is with the Smithsonian Environmental Research Center where he serves as the research program coordinator of the Marine Invasion Research Laboratory. Dr. Miller's background is in marine ecology and marine invasion biology.

Judith Pederson. Dr. Pederson is a marine ecologist and serves in an advisory role with the MIT Sea Grant College Program. Dr. Pederson has worked with the MA Coastal Zone Management and her recent work has focused on marine bioinvasions.

Michael Semmens. Dr. Semmens is with the Department of Civil Engineering at the University of Minnesota. Dr. Semmens background is in environmental engineering and the physical and chemical processes of water and wastewater treatment.

Greg Stapleton. Mr. Stapleton is with the USEPA, Engineering Analysis Division. Mr. Stapleton's background includes environmental and mechanical engineering, research and development of shipboard pollution abatement systems and development of vessel regulations.

Craig Taylor. Dr. Taylor is with the Woods Hole Oceanographic Institution. Dr. Taylor's background is in marine microbiology with emphasis on techniques to study microbial ecology, including instrumentation development. He is currently working on a USCG RDC project auditing ballast water treatment alternatives.

Thomas Waite. Dr. Waite is with the College of Engineering at the University of Miami. Dr. Waite's background is in environmental engineering with particular emphasis on water treatment processes. Dr. Waite has more than six years of experience on ballast water treatment systems including the design, construction, and operation of large-scale ballast treatment systems. He is currently testing ballast water treatment technologies as part of a USCG RDC funded project.

2.3 West Coast Workshop Participants

This section briefly summarizes the expertise of the West Coast workshop participants. The contact information for these individuals is included in Appendix B.

Gloria Casale. Dr. Casale is a Doctor of Medicine with the Association of Teachers of Preventative Medicine. She is currently a Fellow in Healthcare Policy and has interests in the public health issues associated with introductions of nonindigenous species.

Timothy Cowles. Dr. Cowles is with the College of Oceanic and Atmospheric Sciences at Oregon State University. Dr. Cowles' background is in biological oceanography with particular expertise in plankton ecology. Dr. Cowles has studied the life histories, distribution patterns, and responses to physical conditions and processes of both phytoplankton and zooplankton.

John Ferguson. Dr. Ferguson is with the Department of Civil and Environmental Engineering at the University of Washington. Dr. Ferguson's research is in the area of water and wastewater processes, bioremediation of chlorinated compounds, corrosion in drinking water systems and anaerobic biological treatment.

Jonathan Geller. Dr. Geller is with Moss Landing Marine Laboratories. Dr. Geller's research interests include the population genetics and phylogeography of invasions, molecular systematics, molecular ecology and functional genomics. Dr. Geller has worked on the Coos Bay Ballast Water Study and is evaluating the microbial diversity in ballast water using DNA sequencing techniques.

Russell Herwig. Dr. Herwig is with the School of Aquatic and Fishery Sciences at the University of Washington. Dr. Herwig's background is in aquatic microbiology/microbial ecology. He is currently involved in sampling ballast tanks of ships entering Puget Sound and a study evaluating ozonation in ballast water tanks of an oil tanker.

Roger Phillips. Mr. Phillips is the Applied Research Manager with the Monterey Bay Aquarium. Mr. Phillips' background is in botany and oceanography with particular interests in nearshore marine ecology and kelp forests. Through his position at the aquarium, Mr. Phillips has expertise in aquarium seawater systems including water quality chemistry, life support system design/troubleshooting, and exotic species treatment systems for displays of non-native species.

John Sansalone. Dr. Sansalone is with the Department of Civil and Environmental Engineering at Louisiana State University. Dr. Sansalone's background is in the research and development of water and solid phase treatment systems and engineered unit operations and processes.

Terry Sutherland. Dr. Sutherland is a research scientist with Fisheries and Oceans Canada. Dr. Sutherland's background is in biological oceanography including plankton ecology and benthic ecology.

Mark Sytsma. Dr. Sytsma is with Portland State University. Dr. Sytsma's expertise lies in the taxonomy of aquatic plants. Dr. Sytsma is active in aquatic nuisance species management planning in the Pacific Northwest and has organized the Pacific Ballast Water Group to address coastal ballast water issues.

3.0 EAST COAST WORKSHOP

3.1 East Coast Daily Overview

Day 1. The first morning of the conference included a brief welcome, overview of the goals and objectives of the workshop and an introduction of the participants to each other, as well as to the Groupware system. Dr. Richard Everett from USCG Headquarters and Dr. Robert Hiltabrand from USCG RDC gave an overview of the USCG Ballast Water Program including the current goals and future directions. The workshop continued with three additional presentations. Dr. James Carlton, Director of the Maritime Studies Program of Williams College and Mystic Seaport, gave a comprehensive overview of ballast water biology and concerns, particularly as it relates to the development of a standard for ballast water. Dr. Whitman Miller of the Smithsonian Environmental Research Center (SERC) presented the results of recent studies of BWE compliance, as well as exchange efficiency and efficacy. Gregory Stapleton of the EPA's Office of Water described EPA's approaches and lessons learned in developing standards and factors that should be considered for development of biological or treatment standards within a regulatory framework.

Following the presentations, participants were asked to address various questions designed to determine the characteristics of a standard; that is, the desired attributes of a ballast water standard. This discussion resulted in raising many different considerations. Following an afternoon of oral deliberations, the participants came to a consensus that ballast water standards should be developed for three different functional groups of organisms:

- Coastal holoplankton, meroplankton, and demersals (including all life stages);
- Photosynthesizers (including phytoplankton, cysts, and algal propagules); and
- Bacteria and viruses (including pathogens).

Based on morning discussions and the consensus of participants at the end of day 1, the workshop facilitators modified the agenda for the following two days to allow the participants to address standards development for each individual functional group identified.

Day 2. On the second day of the workshop, the participants were divided into three working groups of 3-4 people based on their areas of expertise. The groups, each made up of a mix of scientists and engineers, represented the functional groups defined the previous day. The groups were asked to develop a short-term (within the year) and long-term (in 5 years) ballast water treatment standard for the functional group they represented.

Each group was asked to address 15 questions to arrive at short-term and long-term standards for their functional group. They were given the morning to answer these questions and draft the ballast water treatment standards. During the afternoon session, each group presented the draft standards for their functional group. During the presentations, all participants were encouraged to discuss each groups findings on the proposed standards. Although participants did not formally vote to approve or disapprove of each group's standards, the discussions included suggestions/modifications to each and the participants generally supported each proposed standard by the end of the day.

Day 3. On the final day of the workshop, the participants were asked to address issues relating to verification and certification. Members from the USCG defined the verification and certification process and how they envisioned each as it relates to ballast water treatment.

The participants again separated into the same small groups and addressed design recommendations for verification and certification for their appropriate functional group. Each group was provided with the same list of questions to guide them though the issues. The small groups were given time to work on the questions and presented their results to the overall group prior to conclusion of the workshop. At the end of the workshop, participants were asked to provide recommendations for future research.

3.2 Synthesis of Topics from the East Coast Workshop

The participants were asked to discuss and recommend the key attributes characterizing a ballast water standard, the quantitative criteria for a ballast water standard, and protocols for verifying/certifying the standard. Participants were also asked to recommend research necessary to further the development of ballast water treatment standards. This section is a summary of discussions the participants had on each topic. The questions participants were asked to consider in their discussions and in developing their standards are provided as tables throughout the document.

3.2.1 Characteristics and Basis of a Standard

The characteristics and basis of the standard were considered through discussion of the key attributes a ballast water treatment standard should possess. These questions addressed by the workshop are shown in Table 1. In addressing these questions the discussions focused on the following topics and concepts:

- Feasibility of developing a biological standard
- Appropriate standard types (e.g., management, performance, process or water quality)
- Standards that are based on relative measures versus those based on absolute values
- Level of protection provided
    - Meaningful biological reductions and how to measure
    - Acceptable level of protection
    - Predictability of invasion
    - Application and use of risk analysis

Table 1. Questions Considered During Discussions of the Characteristics and Basis of the Standard.

Characteristics of a standard

What do we mean by a biological standard?

Should the USCG implement a management, process, performance, or water quality standard?

Basis of a standard

Should the standard be based on the effectiveness or biological efficacy of exchange, capacity of the receiving system, Best Available Technology or some other basis?

    - Capacity of the receiving system to accept species
- Use of best available technology

The initial considerations focused on whether or not a standard should be based on biology and whether it was feasible to develop a biological standard, that is, one that is based on organisms. There was general agreement that the standard must be biologically based (i.e., based on living organisms) because the goal of ballast treatment is to remove unwanted organisms.

The discussions concerning the feasibility of developing a biological standard focused on several attributes or characteristics of a biological standard including the merits of a relative (e.g., percent reduction) versus absolute (numeric value) standard, the applicability of a risk-based approach, and the type of standard that could be implemented by the USCG. Although the participants discussed all of these issues in some level of detail, a large proportion of the discussions on the characteristics of the standard centered on whether the standard measure should be an absolute value or a percent reduction.

During these discussions the participants agreed that the standard should reflect a "protection level" that significantly reduces the risk of biological invasions and that the standard should be sufficient to reduce the inoculation size (overall number of water-borne organisms) to some extent. However, during these deliberations, participants highlighted the current lack of scientific ability to predict which organisms will invade and the minimum number of organisms necessary for a successful invasion. Therefore, the extent of reduction and how it is determined to be biologically meaningful is difficult to address and recurred as a challenge throughout the workshop deliberations.

Participants who supported an absolute value standard pointed out that the water quality standards, including drinking water, are based on specific values and units. For example, the acceptable bacterial criterion for recreational waters is based on a specific number of bacteria per volume, not a percent reduction. Under a relative reduction scenario, one could achieve a 75 percent reduction of an enormous number of bacterial cells. However, the remaining number of cells still could be a large number of bacteria and it is possible, under certain conditions, that the 25 percent remaining are more than capable of invading new systems and creating bacterial explosions. Pro-absolute participants also pointed out that without setting an absolute standard it will be impossible to determine future organism discharge from ships.

Participants who favored a relative standard debated that a scientifically defensible absolute value could not be determined without knowing the maximum "allowable concentration" of many taxonomic groups that are considered problematic. Since there is no stereotypical invader, it would be impossible to set those values with any certainty. Some participants also favored a relative standard measure because it would accommodate integrated treatment approaches and allow technologies to be implemented more quickly.

Throughout the debate, participants reached consensus that an absolute standard could be developed for a "worst-case" scenario and could, as a starting point for assigning a value to the standard, be based on existing standards. They indicated that a conservative approach should be taken. At the end of the discussions, participants agreed that using a percent reduction approach when dealing with bacteria and other asexually reproducing organisms is not appropriate because a population explosion could result from a small number of surviving organisms. Thus, it was concluded that while a percent reduction approach does reduce the potential threat and may slow the rate of introductions, it does not prevent invasions. At this time, all participants agreed that they wanted to head in the direction of developing an absolute standard (i.e. ballast water discharge should not contain more than X organisms).

The participants briefly considered whether the standard should be one of the following types: management, performance, process, or water quality. An example of a management standard is one based on the most applicable ballast water management option for a particular situation. A performance standard is one based on the specific performance of a technology (or management option) and requires that treatment produce a particular result. A process standard is based on the implementation of a specific technology or management option. However, unlike a performance standard, a process standard is not concerned with quantifying the efficacy of the treatment. A water quality standard is a standard similar to those required for drinking water or wastewater treatment systems and are generally absolute maximum levels that cannot be exceeded.

The participants dismissed management and process standards as options since they are not consistent with biological-based, absolute standards. However, participants' opinions varied on whether the standard should be performance-based or more akin to water quality standards. Several stated that the standard should be based on performance, because it would provide some leeway on which methods could be used to achieve the standard. Some suggested that the water quality standard model would be the most useful and defensible and can be correlated to both process and performance. Consensus on this issue was not achieved and discussions quickly led to the types of measures that should be developed in support of the standard. The participants considered whether the framework (e.g., theoretical or demonstrated effectiveness of ballast water exchange, Best Available Technology (BAT), and capacity of the receiving system) recommended by the Ballast Water Shipping Committee (BWSC) should serve as the basis for developing a standard during this workshop.

The participants universally agreed that the standard should not be based on capacity of the receiving system. The basis of this agreement was founded on the inherent variability across ecosystems and the near impossibility of establishing a biological assimilative capacity of all potential ecosystems receiving ballast discharge to accept alien species (i.e. when does an invader become detrimental). Moreover, it was pointed out that the capacity of the receiving system has little meaning in invasion biology since it presupposes that some level of environmental tolerance exists that can be counted on to aid treatment. The participants agreed that the issue of estimating an assimilation capacity for a variety of different organisms in very different, and complex hydrographic systems and ecosystems is a research problem that is simply not resolvable at this time.

The participants were divided on whether the standard should be based on BAT. Several participants stated that the standard should be based on science (i.e., scientifically defensible research on impacts to the ecosystem), but indicated BAT could serve as an interim approach for setting standards. Others felt that setting a standard that is not attainable by current technology is not worthwhile. Implementing a BAT standard would allow the development and installation of treatment technologies to progress more quickly and provide at least some benefit for the near future. Some participants suggested that a phased standard (e.g., one that may be based on BAT initially and becomes more stringent as more scientifically defensible information becomes available) could be a potential approach for setting the standard. The participants did not resolve their differences on this issue.

Participants felt that ballast water exchange (BWE) should not be discarded as a potential treatment option. They agreed that if BWE could be demonstrated to achieve the treatment levels required by the standard, it should remain as a valid management option. However, the participants were not in favor of using BWE as a benchmark for the treatment standard because there is insufficient demonstration of the biological efficacy of exchange as it relates to the various ballast tank configurations, organism survival, and regrowth within ballast tanks after exchange. In fact, there is speculation that BWE may "refresh" some organism populations. The discussions clearly resulted in a group determination that BWE should be categorized as a technology to treat ballast and, therefore, would be included with all other technologies under a BAT approach.

The workshop participants considered whether a standard aimed at reducing the risk of biological invasions would have to be measurable through direct sampling or some type of surrogate or indicator organism approach. Surrogate in the context of these discussions is used as an organism added to a test system and which represents a natural set of organisms or organism function. A surrogate measure could also include a process or management measure to indicate that a process was satisfactorily completed or that compliance with a management action had been met. An indicator is a species drawn from a natural population that represents a set of species or species group or function or is a measurement intended to represent biological activity (e.g., chlorophyll a or adenosine triphosphate (ATP)). Several participants suggested that indicator organisms should include those that are most difficult to remove (either physically or through inactivation or kill treatments) because removal of highly resistant organisms better ensures that all other organisms would be destroyed as well. Therefore, some felt that a resistant life stage such as a phytoplankton cyst might be an appropriate indicator.

The discussions surrounding approaches to a standard and type of biological standard to develop led to a number of questions and considerations regarding the specific biological species or functional groups that would be targeted by the standard. These considerations led to an impromptu, facilitated discussion that was aimed at determining the participants' thoughts and recommendations on ballast water treatment goals and on the organisms that needed to be removed from ballast water prior to discharge.

The discussions pointed out concerns regarding invasion from the smallest organisms (i.e., viruses and bacteria) to prevention of the introduction of larger species, such as zooplankton or the larval forms of invertebrates or fish. Participants were in full agreement that treatment goals were to reduce the probability of invasion, thereby diminishing the deleterious effects to the economy, the ecology, and human health.

Participants discussed what needed to be removed from ballast water to achieve these goals. Initially the participants discussed using a size criterion to reduce the risk of invasions but quickly conceded that this approach would not address some of the smaller larval organisms and bacteria. All participants felt it was equally important to remove zooplankton, phytoplankton, and bacteria from ballast water discharge. Since it was clear to the participants that a standard developed for one group of organisms (e.g., bacteria) may be very different from what is needed for another group of organisms (e.g., fish), participants identified three general classifications for the organisms of concern based on functionality. They recommended that each of the following functional groups be assigned a set of descriptors and characteristics, as well as a unique standard.

- Coastal holoplankton, meroplankton, and demersals (including all life stages)
- Photosynthesizers (including phytoplankton, cysts, and algal propagules); and
- Bacteria and viruses (including pathogens).

Two other topics were scheduled for discussion during this session – Geographic Scope and Applicability, and Level of Protectiveness to the Environment. However, the above discussions extended over the entire day, and to a certain degree superseded and cut across these topics. Therefore, they were not discussed under this session but were touched upon in the standard setting session discussed below.

3.2.2 Setting the Standards

Working in small groups defined by the three functional groups, the participants were asked to draft standards aimed at reducing the risk of biological invasions from ballast water. The groups addressed a series of questions (Table 2) aimed at supporting development of both draft short-term and long-term standards. Synopses of the discussions are presented below.

3.2.2.1 Coastal Holoplankton, Meroplankton and Demersals

The coastal holoplankton, meroplankton, and demersals functional group was defined as containing a wide range of organisms from approximately two microns in size to fish several inches long. The organisms comprising this functional group can be scarce to very abundant (i.e., in excess of 50 million per liter). However, they are generally found in lower concentrations than bacteria. Introduction of species in this group may have profound impacts on receiving systems from both the ecological and economic perspectives. Most species in this group reproduce sexually, but there are organisms within this functional group that reproduce asexually. Thus, it was felt that those that asexually reproduce should drive the treatment standard because smaller numbers may pose a higher risk.

Participants in this working group recommended that the short-term standard for this functional group should require that existing ships remove 99 percent of all life stages of these organisms and that new ships should meet a long-term standard of removing all coastal zooplankton to a non-detectable level. Additionally, the group participants indicated that if BWE could be improved to meet this 99 percent removal of all coastal zooplankton life stages, then it would be an acceptable treatment method. The participants suggested that biological indicators could be used for measuring the efficacy of a treatment but also indicated that surrogates could be used, and if used, should include a mix of species of various taxa and size classes as a measurement of the standard. If indicators or surrogates are used as part of the standard, the working group recommended that they be representative of the function, behavior or life cycle of a broad spectrum of organisms. However, for this exercise the participants assumed the standard for this group would apply at the point of discharge (rather than intake) to eliminate any potential for re-growth of asexually reproducing organisms.

Because invasions from this group of organisms have resulted in large-scale ecosystem changes, the workshop participants indicated that benefits to the ecosystem and economy are primary goals for this standard.

Table 2. Questions Used to Focus Development of Standards Statements.

What do we know about the functional group?

What indicator(s) should be established as a measure of the standard?

Assuming the standard will be applied at the point of discharge, what confounding factors are possible for the recommended measure if treatment is at some other point than at discharge?

What are the numeric value, the qualifiers, and the narrative criteria of the standard?

What environmental factors will influence the standard?

How much data are required and what level of statistical confidence is required to defend the standard?

Are existing data sets adequate to support the measure and standard?

What research is necessary before the measure can be successfully implemented?

How often should the standard be reviewed? What is the review process?

Where does the standard focus most: human, economic, or ecosystem benefits and why?

Should a national standard be developed or should the standard(s) include regional specificity?

How important is it to consider similarities between the ports of origin and discharge?

How important is it to consider known undesirable ecological or health issues of the port of origin?

3.2.2.2 Photosynthesizers

This functional group contains phytoplankton species that range from 2-1000 microns, as well as algal fragments and propagules 1 cm or larger. The vegetative cells of this group all contain chlorophyll and ATP, and approximately 10 percent of the species form cysts or spores that can be highly resistant to a wide range of environmental conditions. The organisms in this group reproduce asexually. Very little information is available regarding the minimum inoculum size required for a successful invasion by organisms in this functional group, but participants thought it to be very small.

The participants defined the short-term standard to include 95 percent removal or inactivation of all phytoplankton cells and life cycle stages. The long-term standard they developed was targeted at removal or inactivation of all phytoplankton cells and algal propagules, and established the theoretical excess invasion risk at 1×10^{-3} (i.e., the risk of invasion should be no more than one organism in 1000). The participants recommended that representative species of "nuisance" phytoplankton be potential measurable indicators of the standard. Filterable chlorophyll was recommended as a possible indicator, with the caveat that it may not be a primary indicator of a treatment's success since chlorophyll degradation can be slow after cell death. ATP was also listed as another indicator; however, it is not a measure that is specific to organisms in this functional group.

An additional consideration identified for this functional group is the potential that some species may form resistant cysts or spores during transit. Therefore, it will be more effective to treat for these organisms during intake as the more resistant life stages will present more of a treatment challenge upon discharge.

Because many of the organisms in this group have recognized public health, fisheries, and ecosystem impacts, the participants indicated that the ballast water treatment standard for these organisms would benefit human health, the economy and the overall ecosystem.

3.2.2.3 Bacteria and Viruses

This functional group consists of bacteria and viruses, including pathogens. These organisms are very small, can cause serious problems and can reproduce asexually. Many treatments (i.e., mechanical separation) that might work for the other functional groups were not believed to be as effective for these organisms. Participants in this working group decided that, for these organisms, the ballast water treatment standard should be a water quality based standard using *Enterococci* or *E. coli* as indicators for saline waters or freshwater/brackish waters, respectively. They felt the extensive literature on water quality standards for wastewater and drinking water supported application of current water quality criteria to this functional group. Current recreational water quality standards state that *Enterococci* should not exceed 35/100 mL or *E. coli* should not exceed 126/100 mL in water discharge; these were recommended for the standard. The workgroup participants noted that the proposed standard assumes technology exists to achieve these values and that it can be adapted to old and new ships. Similar to the functional group containing the photosynthesizers, the bacteria and viruses reproduce asexually. It was pointed out, however, that unlike the photosynthesizer functional group, these organisms are capable of rapid growth under many different conditions (i.e., dark or more hostile conditions). Thus, there was a concern about organism regrowth if treatment occurs during ballast water uptake. The workshop participants agreed that it would be more practical for treatment to occur at discharge.

With respect to the benefits of the ballast water treatment standard for this group, the standard was believed to benefit primarily human health (because many of these bacteria and viruses are known to cause health-related problems). It was indicated, however, that these organisms could impact the economy and overall ecosystem health through fisheries resources.

3.2.2.4 General Considerations and Summary

There were several general agreements within and among the three working groups regarding the characteristics of the ballast water treatment standard. All participants agreed that the standards they developed for their respective functional group should be nationally based. However, the participants supported the concept of flexible standards to ensure that regional concerns could be addressed. For example, the standard should be flexible enough to accommodate the biological and hydrological differences between the various ports (i.e., receiving systems). The greatest difficulty regarding this was recognized as an inability to evaluate the threat of biological invasion of each individual region from these diverse groups of organisms. It was considered, however, that if a mechanism existed to empirically show the risk of invasion from organisms transported from one port to another is negligible, then this empirical evidence should be accepted as equivalent to technology resulting in no risk of invasion. Relative to the review of the standard, participants from two groups felt that every five years was probably sufficient unless new data are found. The phytoplankton workgroup participants felt that every two-three years might be more adequate.

The short-term and long-term standards developed by each group are presented in Table 3. Participants felt the long-term standard should support a level of protection that strives for no introductions of invasive species (regardless of functional group). Although the long-term and short-term standards for bacteria and viruses are the same, the participants recommended a review of the long-term standard in 2006. There was discussion relative to what was actually feasible in the short-term for implementing the standards. Although the participants clearly stated in earlier sessions that the recommended standard must be an absolute value, they felt that in the short-term a percent reduction might be all that is feasible at least for the coastal holoplankton and meroplankton and the phytoplankton groups. The participants felt it critical to once again note that in the short-term these percent reductions will not prevent invasions from occurring but will simply slow the rate of invasions. Preventing all invasions is the ultimate long-term goal communicated by the participants.

Table 3. Summary of the Short- and Long-term Ballast Water Treatment Standards Based on the Three Functional Groups of Organisms Defined During the East Coast Workshop.

Functional Group	Short-term Standard	Long-term Standard
Coastal holoplankton, meroplankton and demersals	99 percent removal of these organisms and their life stages	All of these organisms and their life stages should be removed
Photosynthesizers: phytoplankton, cysts, algal propagules	95 percent removal or inactivation of these organisms and their life stages	All of these organisms and their life stages should be removed or rendered inactive
Bacteria, viruses (including pathogens)	*Enterococci* should not exceed 35/100 mL or *E. coli* should not exceed 126/100 mL in water discharge	*Enterococci* should not exceed 35/100 mL or *E. coli* should not exceed 126/100 mL in water discharge

3.2.3 Design Elements for Approving Treatment Methods

Working in the small groups defined by the three functional groups, participants discussed issues and concerns relative to methods for approving treatments for use against invasive species. These included issues such as:

- Experimental design
- Shipboard vs. land-based testing
- Application to existing vs. new ships
- Frequency and duration of testing
- Source conditions (e.g. water quality) for water used in testing
- Key indicators of performance
- Use of surrogate species

Table 4. Questions Used to Develop Design Recommendations for the Standards Testing.

What are the key elements of experimental design for verification of the standard?

Should there be additional requirements for certification?

Should verification/certification include shipboard testing?

What would be an adequate level of testing aboard ship?

What other parameters should be measured in addition to the measure of performance?

What frequency and duration of testing is required?

What do we use for source conditions?

What protocols/conditions should be used to evaluate a treatment onboard ship? Are they different from land-based testing?

For onboard testing, what types of shipping routes would be considered representative?

What other parameters should be measured in addition to the measure of the standard?

How many onboard tests are adequate to ensure the treatment is meeting the standard?

The questions used to guide the workshop discussions in the area of standards testing and protocols are shown in Table 4.

During the discussions, the participants raised questions concerning certification and verification of treatment technologies. As clarified by the USCG, verification is testing to determine if a specific treatment system performs according to design. Verification testing is conducted to verify the manufacturer's claim and provide consumers with objective performance information. Certification, however, is a regulatory process. Certification testing is conducted by the USCG to determine if a specific treatment system meets criteria and standards developed by the USCG. If the testing indicates that a treatment meets established criteria and standards, the treatment method (e.g. equipment) receives USCG certification as an approved treatment method.

Each work group indicated that indicator species and surrogate species need to be identified for any verification or certification protocol. Moreover, consistent use of the indicator/surrogates was believed to be essential to the protocols to ensure test validity. The participants recommended that treatment methods and equipment be challenged under a wide range of environmental conditions. Environmental conditions representative of the conditions ships traveling throughout the world might experience were recommended. For example, salinity conditions from freshwater to estuarine to full oceanic salinities (e.g., 0 – 35 ppt) were suggested for evaluation in combination with a range of temperatures (e.g., 0 – 30 ºC). In addition to these parameters, the workshop participants suggested that the testing should also occur across differing ranges of pH, suspended solids and dissolved oxygen. Defining a realistic "worst case" condition and evaluating the treatment technologies and methodologies under those conditions was felt by many to be critical to the success of any verification/certification test.

Many participants felt that along with testing on the smaller/laboratory scale, shipboard testing is critical and must be conducted. The rationale was that testing centers cannot reproduce the operating conditions of the ship. The workshop participants also recognized that protocols to conduct onboard ship treatment evaluations will be difficult to develop and that it may not be possible to use the same indicator or surrogate species used in smaller scaled studies in shipboard trials. Testing that ensures the treatment system continues to meet the standard when it is first installed and when it is several years old was suggested. One working group indicated that long-term monitoring of the treatment system to evaluate how well the system works as it ages will be a necessity. Like laboratory testing, participants recommended that all shipboard trials undergo a diverse range of environmental conditions (i.e., temperature, salinity, etc.). Moreover, it was suggested by participants that shipboard trials be continued until adequate data have been collected to statistically or meaningfully demonstrate that the standard has been met, and confidence has been described around the "zero" measurement for any absolute standard.

3.2.4 Research Considerations

Areas that require research were identified throughout the deliberation of the workshop. The research areas or needs identified by the East Coast Workshop have been combined with those of the West Coast Workshop in Section 5.0 of this report.

4.0 WEST COAST WORKSHOP

4.1 West Coast Daily Overview

Day 1. The first morning of the conference included a brief welcome and an overview of the goals and objectives of the workshop. Ms. Gail Roderick from the USCG Research and Development Center (RDC) gave an introduction on the issues surrounding aquatic nuisance species invasions and ballast water. Dr. Richard Everett from USCG Headquarters and Dr. Robert Hiltabrand from USCG RDC gave an overview of the USCG Ballast Water Program including the current goals and future directions. Dr. Everett also gave a review of ballast water exchange including the efficacy of exchange and what is currently known regarding this practice. Mr. Gregory Stapleton of the EPA's Office of Water gave the final presentation and described EPA's approaches and experiences in developing standards and additional considerations for development of biological or treatment standards within a regulatory framework.

Table 5. General Questions Raised During the West Coast Workshop.

1. *There are many unknowns regarding the threat of potential invasions but, based on what is known, what issues need to be considered as part of the standard development process and what information will assist us in developing the standard(s)?*

2. *In your opinion, what are the obstacles, or constraints, to developing ballast water treatment standards?*

3. *What clarifications do you need regarding the workshop objectives, desired results, or any of the presentations before we can begin the standard and protocol development sessions?*

Following each presentation, participants were asked to comment and raise questions on the presentation using the Groupware system. Additionally, based on the information presented, they were also asked to respond to three general questions (Table 5). Following this Groupware exercise, all participants openly reviewed and discussed the questions and comments they raised on the presentations as well as the responses to the three general questions.

During the afternoon of the first day, the participants were asked to answer questions designed to determine the desirable characteristics of a standard (Table 6). The desired attributes of a ballast water standard included the goals of the standard, protectiveness, scope of the standard (national vs. regional), basis of the standard (BWE, BAT, risk, capacity of the receiving system) and applicability of the standard. The remainder of the afternoon was an open discussion aimed at achieving consensus and drafting appropriate consensus statements for each question. While consensus was reached in the responses to these questions, participants requested that the questions be revisited later during the workshop.

Day 2. Day 2 of the workshop began by recapping Day 1 discussions and reviewing the consensus statements achieved on the standard characteristics. Following those discussions, the participants were divided into three smaller (3-4 people) working groups. Both scientists and engineers comprised each group. The groups were asked to develop a short-term (i.e., can be implemented over the next few years) and a long-term (i.e., can be implemented over the next decade) ballast water treatment standard. Each group was asked to address 10 questions (see

Section 4.2.2) designed to facilitate development of short-term and long-term standards. The groups were given the morning to answer these questions and to draft the ballast water treatment standards. During the remainder of the morning and early afternoon, each group presented their draft standards. Participants discussed each presentation and the rationale used to develop the standard. A facilitated discussion focused on achieving consensus on a single recommended long- and short-term standard followed these discussions. Consensus was reached on the long-term standard statement. However, the participants could not reach consensus on a short-term standard in part due to their need to more fully understand the status of knowledge and research regarding ballast water issues. All participants were extremely uncomfortable with establishing or recommending a quantitative standard that targeted anything less than 100 percent inactivation or removal (consensus on the long-term standard). The participants strongly indicated that anything less than 100 percent would require reliable data sets on the relative risks of invasions. Since these data are not currently available, the participants felt strongly that it would be difficult to establish a sound scientific basis for determining a meaningful short-term standard that was less than 100 percent removal/inactivation. They also felt strongly that their discussions should thoroughly review the status of current knowledge and research results to determine the potential for developing a less stringent short-term standard. The ensuing discussion continued during the afternoon session and enabled the workshop participants to come to a higher understanding of the issues.

Day 3. On the final day of the workshop, the participants developed a consensus statement for a short-term standard. Once this was agreed upon, the consensus statements on the characteristics of the standard developed on Day 1 were reviewed and revised based on the discussion of the workshop. A final consensus on these revised characteristics statements was taken via vote tally. The participants then provided recommendations of needed research.

4.2 Summary of the West Coast Workshop

The topic areas the participants were asked to address included general issues, defining the key attributes that characterize a ballast water standard, developing a short-term and long-term standard, recommending protocols for verifying/certifying the standard and identifying research areas. The West Coast participants did not comprehensively address the topic pertaining to verifying/certifying the standard, but information regarding this topic can be gleaned from discussions pertaining to the other topics. Similarly, research recommendations necessary to further the development of ballast water treatment standards were identified throughout the discussions and as specific input. The specific questions asked of the participants are provided in the tables of the sections that summarize the discussions on each particular topic. Section 4.2.1 summarizes the general issues considered and Section 4.2.2 summarizes the characteristics of the standard and the basis for standards that were developed in small working groups.

4.2.1 General Questions

Following the overview presentations, participants were asked to respond to three general questions (Table 5) regarding issues that need to be considered during standards development, and obstacles and constraints to ballast water standards development. Consensus on these issues was not sought nor offered. Thus, this section provides a summary of the thoughts provided at this stage of the workshop.

The participants identified many unknowns relative to the ballast water treatment standard. These include the current lack of knowledge of the relationships among the number of organisms released, the spatial and temporal setting for release, and the actual likelihood of invasion. Such questions and unknowns clearly identified the need for more research. Additionally, a measure that would demonstrate a reduction of aquatic nuisance species invasions was identified as an issue that needed attention. Other issues identified as requiring clarification prior to standard development included better understanding the efficacy of the various treatment technologies that presently exist (including ballast water exchange), the water quality parameters that affect treatment effectiveness for specific organisms, and the need to select specific indicator organisms for treatment effectiveness research and testing.

The participants reviewed the four standard frameworks identified by the BWSC. The participants indicated that ballast water exchange should not be used as the basis for developing the standard as current research studies have not adequately addressed the biological efficacy of this practice. On the other hand, the participants were not certain what an alternative basis for the standard should be (e.g., a performance-based standard or a water quality based standard). They felt that a risk-based standard would not be possible for most organisms and ecosystems because the factors contributing to a successful invasion are still unknown. However, some felt that a risk-based standard may be appropriate for pathogens, and the development of such a standard could use risk-based examples from the wastewater treatment industry. Overall, participants indicated that the basis of the standard would likely need to change with time as better technologies and research results become available.

The sheer complexity of the ballast water/invasive species and biology problem was mentioned as a large obstacle/constraint to developing ballast water treatment standards. In addition to the uniqueness of specific ecosystems and unknowns regarding the susceptibility to invasion, the large number of vessel types and ballasting configurations and the operational constraints of those vessel types were all identified as contributing to the complexity of the issue. The enormous volumes of ballast water that need to be treated, as well as the high flow rates, were also felt to constrain options and add to the complexity. Participants agreed that the lack of reliable and objective data and information on current technologies would constrain the standards development effort, particularly if a standard were to be based on best available technology. Participants also felt that data on current technologies are scattered and unreliable. Privacy issues regarding specific technologies were also raised as a constraint to accessing data and as a factor that could slow research and testing contributing to the standards development process. The last major constraint tabled by the participants was the current lack of measurement tools/methods to assess compliance with any future standard. This discussion identified the need for methods to monitor the efficacy of a treatment system as part of onboard compliance monitoring. Thus, the participants also identified a need for rapid monitoring techniques.

4.2.2 Characteristics and Basis of a Standard

For the West Coast workshop, the questions aimed at characterizing a potential standard were re-worded slightly from those used for the East Coast Workshop. These questions (Table 6) were designed to address issues of protectiveness, scope, and applicability of the standards and were classified into two topics: 1) protectiveness and 2) scope and applicability. These questions were addressed individually in the GroupWare and then discussed by all participants. A synopsis of these discussions is presented in Sections 4.2.2.1 and 4.2.2.2. Section 4.2.3 provides the consensus statements developed by the participants on Day 1 of the workshop.

Table 6. Questions Addressed by the West Coast Workshop Participants Relative to the Characteristics of the Standard.

Protectiveness
What should be the intended goal of setting ballast water treatment standards (i.e. what are we trying to protect)?

What is the minimum level of protection the standard should provide?

What is the maximum level of protection?

Is it possible to implement this level of protection now? If not, why not and what is possible?

Scope and Applicability
Should a national standard be developed or should the standard(s) include regional specificity?

Should the standard account for similarities between the ports of origin and discharge? Known undesirable ecological or health issues of the origin port?

Can or should the standard be based on the effectiveness or biological efficacy of ballast water exchange? The capacity of the receiving system? Best Available Technology? Or other basis?

What is important to remove from ballast water and why?

Is a relative or absolute standard more applicable?

Are there any other insights ***or*** *questions or issues that should be addressed relative to the characteristics of the standards?*

4.2.2.1 Protectiveness

The responses of the participants regarding the goal of the standard clearly indicated the standard should prevent the introduction of nonindigenous species and must also prevent the transport and introduction of toxic and pathogenic organisms. The rationale for this was based on the belief that the standard needs to protect against negative impact to marine ecosystems (ecological health), human health, and the economy.

Participants were clear and in strong agreement that the maximum level of protection should be 100 percent removal of organisms. However, they struggled with identifying a minimum level of protection the standard should provide that differed from the maximum level of protection. The reasons for this were many, and included such concerns as: 1) there is no ultimate minimum level of protection; 2) risks associated with a minimal level cannot be established; 3) anything less than 100 percent requires a value judgment on an acceptable invasion rate or risk of invasion rate; 4) any minimum risk should be based on a known level of risk or a policy decision; and 5) insufficient amount of data is available at this time to establish a defensible minimum**.** As a result, the workshop participants felt there was no acceptable minimum level of protection less than "zero discharge" of organisms since an estimated risk associated with any discharge is not currently possible. Thus, there was agreement among these experts that the maximum and minimum level of protection must be set at 100 percent and the standard should strive for "zero" introductions.

Considerations on whether 100 percent of protection could be achieved today indicated that the state of science and engineering is not yet at that level. Moreover, achieving 100 percent all of the time was considered unrealistic by some since even the best technologies will have failures. Also apparent in the considerations was our inability to define zero based on measurement limitations. If 100 percent removal is the immediate goal, some participants suggested that complete removal of organisms could be technically possible, but only if the cost effectiveness of treatment methodologies was not an issue. Some felt that 100 percent reduction of certain groups of organisms could be obtained at this time through certain treatment types. Others indicated that the efficacies of treatment methods must be assessed and monitored through demonstrated methods designed to achieve consistent accuracy and precision. In general, the considerations pointed to the fact that the present state of the science is not able to achieve 100 percent removal, as there are still many unknowns.

One possible solution to the dilemma of an acceptable minimum level of protection was the use of interim standards based on available technology. A clear direction or consensus could not be developed.

4.2.2.2 Scope and Applicability

The participants generally agreed that a standard should be a national standard that encompasses regional differences. The basis for this agreement was that a national standard would provide for a much less complicated standard and would provide for less confusion during implementation and compliance. However, the national standards should be flexible enough to encompass regional considerations. Further, they agreed that not enough was known about invasibility nationally, let alone regionally to implement geographically specific standards. However, the minority opinion believed that regional or port-specific variations should be considered because levels of invasion risk varied tremendously. At the very least, states and regions should be held to a national standard but could be allowed to set higher standards, if they deem that appropriate.

Participants also discussed whether or not the standard should account for similarities and dissimilarities between ports of origin and discharge ports. The discussions indicate this should not be a focus of the standard due in part to variability that extends from daily to seasonal to annual cycles. Other confounding issues identified by the discussions include evidence that temporal, latitudinal, or climatic factors do not provide protection from introductions. Thus, knowledge of the complexity of the biology, variability in source locations and biology of the sources, and the many other unknowns relevant to this issue supported the conclusion that the standard should be independent of sources. Moreover, research to understand these factors for all possible combinations of ports-of-origin and receiving ports was recommended.

Considerable discussion was held regarding a standard based on ballast water exchange, capacity of the receiving system, or available technology. Most participants agreed that the standard should not be based on BWE or other treatment efficacy. Basing the standard on BWE was not considered acceptable because BWE does not address the goal of eliminating biological invasions. Further, the current lack of knowledge on the efficacy of BWE constrains it from being used as a sound scientific basis for the standard. Many participants indicated that the standard should be based on protectiveness to the resources and human health. Some participants indicated that risk analysis of the receiving system could be considered, but acknowledged that it will be very difficult to assess risk of all species potentially introduced to all receiving systems. Also acknowledged in this discussion was the need to understand the capacity of the system, a risk-based approach, which as previously discussed (see Section 3 of the East Coast Workshop summary) has inherent issues that make the approach difficult at the present time.

The use of BAT as the basis for the standard received considerable attention by this workshop. Some participants raised the concern that a best available technology approach would thwart the evolution of new technology. In the discussions, most participants agreed that best available technology should not be the basis of the standard, because the standard should be based on biological efficacy. Some felt BAT would not provide an adequate level of protection for either environmental systems or human health. This concern was based in part on the sense that the efficacy of the technology is not yet adequate against the goal of no introduction of invasive species and the paucity of information on how well available treatments perform. Others felt the paucity of information regarding invasion biology and ballast water could make it necessary to look at best available technology, as long as flexibility is incorporated into the standard as treatment moves towards a 100 percent reduction.

The consideration of organisms that should be removed from ballast water led to a general list of biological groups and specific species that should be addressed by the standard. These include human and marine pathogens, species that may degrade ecosystem function or beneficial uses, species pathogenic to fish and shellfish, and species used in aquaculture. In keeping with the 100 percent removal goal, some participants indicated removal or inactivation of all living organisms should be targeted by the standard.

The participants were not clear on the distinction between relative and absolute when referring to the standard. For the purpose of this workshop, the term “absolute” was defined as a number that is independent of the strength of the source, and “relative,” as a change from the source number. Several participants strongly believed that an absolute standard was essential, noting that to establish a relative standard, it would be necessary to better understand what the “typical” species mix and abundance was in ballast water. The sense of the group was that data on the biology of ballast water currently could not support the development of a relative standard. An opinion was offered that the standard could incorporate both absolute and relative components, citing, for example, that a relative standard might be possible for pathogens.

The participants raised several other key issues regarding the characteristics of the standard. Most predominantly, participants felt that the standard would need to be flexible on several levels to reflect the current state of the science. Several participants indicated that flexibility would allow the standard to evolve as more effective technologies become available. Also noted was the consideration of differences for new and old vessels. The ability to collect ballast water samples on ships and obtain records regarding treatment and other implementation information were also considered as important to the development of the standard.

The lack of a consistent approach to assessing treatment technologies was identified as an issue that may influence the standard. Standardized approaches were encouraged prior to the establishment of a standard. Participants suggested that the approach to evaluate the technologies should examine species that are indicators for functional groups, address the many different treatment technologies, define a set of biological assays for each specific functional group, and cover a range of oceanographic conditions. The testing of treatment technologies both onboard ship and in the laboratory was recommended. One participant recommended that a performance and process-based approach should be established to assess linkage between lab and field-testing results.

4.2.3 Consensus Statements Developed for the Characteristics of the Standard

After the questions in Table 6 were addressed in the GroupWare and the workshop participants discussed the responses, a set of consensus statements was developed for the characteristics of the standard. A consensus on each statement was achieved based on the discussion summarized above and an active polling of the participants. These statements are:

- Ballast water exchange is not an adequate benchmark.
- The standard should provide for the protection against future invasions of nonindigenous species.
- The maximum level of protection the standard should provide is 100 percent protection from aquatic nonindigenous species and pathogens.
- The minimum level of protection the standard should provide is 100 percent protection from aquatic nonindigenous species.
- The standard should provide for no detectable release of nonindigenous species.
- A national standard should be set.
- The standard should apply to all ballast water discharges regardless of the port of origin.
- The standard cannot be based on the capacity of the receiving system to resist the invasion of aquatic nuisance species.
- At this time, the concept of the receiving system is not applicable to the standard.
- The standard should be directed against all potentially harmful organisms.
- The standard will be based on absolute values.

The participants requested that these consensus statements be revisited after further discussions of the standards were completed. This was done on day 3.

4.2.4 Standards Statements

After the above consensus statements were developed, three workgroups were formed and each was asked to draft standards aimed at reducing the risk of biological invasions from ballast water. Each group was asked to address the same series of questions (Table 7). These questions were designed to assist the participants to develop draft short-term and long-term standards. Each group was also asked to develop a short-term and long-term standards statement. The individual group discussions were recorded in the GroupWare, then the entire workshop discussed each group's result. These initial standards statements developed by the groups are summarized below along with a summary of the considerations of the participants.

Table 7. Questions Used to Help Define the Standard.

What biological, surrogate indicator and/or engineering endpoint(s) should be established as a measurement of the standard?

For a biological standard, what specific species of concern, mix of species, taxa, functional groups or size classes should be considered?

It is assumed the standard will be applied at the point of discharge. What confounding factors are possible for the recommended measure?

What is the numeric value of the standard? What are the qualifiers around the value? Any accompanying narrative criteria?

What environmental factors will influence the standard?

How much data are required, and at what level of statistical power/confidence is necessary to support the promulgation of the standard?

Are existing data sets adequate to support the measure and standard?

How often should the standard be reviewed? What should the review process be?

Should a national standard be developed or should the standard(s) include regional specificity?

Each group essentially developed the same long-term standard although the wordings are different (Table 8). The short-term standards had different statements. As a result, the discussions focused on developing a short-term standard.

All groups suggested that biological indicators (organisms that represent a larger group of organisms or function) should be established as a measurement of the standard, but they did not come up with specific biological organisms or surrogates to use as indicators. None of the groups suggested or addressed engineering endpoints (numeral values) as a measurement of the standard.

One group determined that short-term biological endpoints should be scientifically defensible estimates of removal/mortality of a variety of taxa under various conditions. After discussions, this group modified the relative removal biological endpoint to 100 percent measured removal and mortality based on distinct assays for each taxa group. Another group suggested that one possibility for biological/engineering endpoints would be to use a disinfection approach evaluating responses of organisms using a concentration and time (CT) evaluation, or a bioassay following a disinfectant, or separation followed by a disinfectant. The final group suggested that the short-term endpoints should be that no organisms greater than 50 µm be discharged. This was felt to be a size that is achievable by current technology and that it would remove the most resistant biological species and forms, which are those species with the highest potential for regrowth, as well as pathogens. The group identified the need to establish biological or surrogate endpoints for organisms less than 50 µm. This group also stated that there should be no discharge of human or other pathogens. In the long term, they indicated the biological and engineering endpoints are such that no viable organisms are discharged.

Table 8. Summary of the Initial Short- and Long-Term Standards Developed by the Three Working Groups during the West Coast Workshop.

	Short-term Standard	**Long-term Standard**
Group 1	Scientifically defensible estimate of current performance on a suite of technologies for all functional groups under a range of oceanographic conditions	100 percent removal or inactivation of spiked organisms through taxa-specific bioassays
Group 2	Use existing technology to eliminate harmful organisms at levels of drinking water standards	Use existing technology to eliminate harmful organisms at levels of drinking water standards
Group 3	• For organisms > 50-100 µm: zero organisms in discharge • For organisms < 50 µm: target the most resistant forms, those with the highest potential for regrowth, and pathogens and set a standard that is achievable with current technology	Zero viable organisms in discharge

The three groups presented a range of organisms that should be considered for the standard. The organisms span various size classes and taxa/functional groups including microzooplankton, meroplankton, macrozooplankton, macroalgae, plants, bacteria (such as *Crytosporidium parvaum*), and other pathogenic organisms. Cysts, spores, or organisms that are resistant to various environmental conditions were also identified for consideration in the standard. The groups were consistent in that defining the specific surrogates was identified as a challenge and that ubiquitous highly resistant indicator organisms will be necessary for the standard. The groups also suggested that bioassays that show no viability of those organisms (indicator or surrogate) would be the core of the enforcement of the standard. It was suggested that surrogates would have to be identified for the tests actually employed by a bioassay and that a non-pathogenic surrogate would have to be validated as a proxy for the pathogenic forms. *Cryptosporidium*, an indicator used in the drinking water industry, was suggested for the standard, although concerns were raised about using it. The main concern was whether it is appropriate to use such an indicator since drinking water standards may not necessarily protect ecosystem health. In contrast, others felt that the drinking water standards provide an analogy or a basis through which the CT concept could be adopted for a biological ballast water standard. This issue was not resolved during the workshop.

All participants concurred that the standard must be applied at the point of discharge. Several groups identified that, depending on where the treatment was applied (uptake, in-ballast or during deballasting), there could be regrowth of organisms. The discussions identified that it is important to understand the viability of organisms after treatment and that the term "viability" needs to be defined relative to ballast water treatment. Suggested approaches included time-dependent biological assays for various taxa/functional groups to better examine the regrowth potential. Other confounding factors relative to the point of treatment application include residuals from the treatment process. Concern over residuals formed both from a treatment (e.g. chlorination compounds) or left over from a treatment (e.g. biocides) was raised. Specifically noted were application of other regulations and steps necessary to ensure residuals are not an issue following treatment. For example, any chemical used as a pesticide must be registered with the Federal Insecticide Fungicide Rodenticide Act and a National Pollutant Discharge Elimination System (NPDES) permit is required for discharge to water. The need to apply dechlorination steps (when, how long, etc.) was an example used for other residuals. Thus, the choice of treatment and the resulting residuals were considered a critical factor for the standard and could result in additional test measurements for levels of residuals or by-products.

The groups also indicated that the standard should be national, but one group mentioned that regional issues must be factored into the national standard. Another group stated that the short-term standard should be national, but should point out some regional specifications. This group's long-term standard would incorporate appropriate regional specifications. The groups varied in their opinions on the frequency of standard review. Two groups suggested that assuming the long-term standard would be in place in 10 years, the short-term standard should be reviewed every 2-3 years, with review of the long-term standard every 5-10 years. One group felt that a 5-year review would probably be sufficient.

4.2.5 Revision of Short-term Standard

Following the discussions of the initial draft of standards, the participants were asked to address the pros and cons of the standards they had developed. They were also asked to focus on the standard itself and not on the technology, methodology, or how the standard would be achieved. This evaluation was initially done in the Groupware. However during the preparation of the written responses, participants voiced concerns about developing pros and cons in the absence of consideration of the technology and methods. They also remained uncomfortable with recommending a standard that provided less than 100 percent protection and continued to reiterate that the only acceptable standard was "zero discharge of organisms." To address these issues, the participants requested that they thoroughly review the status of current knowledge and research to determine what knowledge was needed to develop a standard, particularly one that is less stringent than discharge of "zero organisms." This discussion continued for the balance of Day 2. The summary below reflects the written input developed initially on the pros and cons of the standard developed and the general discussion on data gaps, as well as other concerns. These discussions continued throughout the afternoon of the second day of the workshop and early on Day 3. These considerations eventually resulted in the participants preparing a single short-term standard. This is presented at the end of this section.

To address the potential to develop a short-term standard that is less stringent than "zero discharge," the workshop participants reviewed each subgroup's proposed short-term standard. The following is a summary of those deliberations.

Participants mentioned that Group 1's standard does specifically address the issue of reducing invasions and is neutral to the range of possible technologies. The use of organisms spiked into a bioassay was also considered. While some support was voiced for the spiking experiments proposed to measure the efficacy of the treatment, participants pointed out that use of the approach in a scientific defensible manner would be difficult (if even possible). It was also suggested that this approach would require a substantial amount of new information, which in turn, implied time and money would be needed. Some thought these could be substantial. Other participants stated that they were uncomfortable with the spiking experiments due to limitations from factors such as representativeness of the species selected and the logistics of culturing large volumes of these species. They indicated that experiments would also need to be performed with natural assemblages of organisms to validate the selection of spiked organisms.

Participants pointed out that the short-term standard developed by Group 2 adopts an existing regulatory standard aimed at protecting human health. The Group 2 members indicated that it therefore should provide adequate environmental protection. There was some concern that this standard only addressed the microbial content of ballast water. The concern was that although drinking water standards are set for microbial species, those standards must still remove larger organisms (i.e., we don't want fish in our drinking water). The application of CT-type treatment and use of surrogates proposed for the Group 2 standard were believed by some to have number of advantages compared to other technologies. The stated advantages included: a proven track record for more than 30 years in the drinking water industry; measurement of concentration and time are straightforward; disinfection residuals are short-lived; technologies exist to remove residuals; application of tablets or dry forms of disinfectants have demonstrated safety and reliability for decades; and the technology of disinfection will not deteriorate over time like a more mechanical system. Several participants indicated that because the scale of the ballast water problem is so large and diverse, any solution that is not simple, reliable, economical and easily verified would not be successful. Thus, concern that the CT approach may not offer an acceptable solution was voiced.

To the participants, the Group 3 standard appeared to be neutral to technology and provided for both a quantitative discharge limit for larger organisms and a BAT approach for reduction of smaller organisms. One drawback identified to this approach was the requirement of no organisms greater than 50 µm. This was felt by some to be restrictive of the technologies that can be used and that it would likely require a multiple step treatment process. The Group 3 standard was the only draft standard that used a size and taxa specific approach to eliminating potentially harmful species.

These discussions continued on Day 3. To reconcile the different short-term standards statements, the participants were asked to define a standard statement upon which they could agree. They decided to modify the proposal standard from Group 3. Throughout these discussions, they developed and reached consensus on the following short-term standard statement:

> Discharge should not include organisms greater that 50 μm and should be treated to meet federal criteria for contact recreation (35 *Enterococci* /100 mL for marine waters and 126 *E. coli* /100 mL for freshwaters).

Following the development of this standard, the participants revisited the consensus statements developed on Day 1 for the standard characteristics. The review of these consensus statements was requested to ensure the statements reflected a final consensus based on all discussions held during the workshop. These revised consensus statements are presented and discussed in Section 5.0 along with the consensus statements agreed to by the East Coast participants.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This section provides a summary of the standards developed by both workshop participants and describes those characteristics of the suggested standards that were common between the workshops. Also presented are general recommendations developed by the workshops for the protocols as well as research needs. Section 5.1 summarizes the standards and consensus characteristics of the standard. Section 5.2 conveys general recommendations for testing protocols. Section 5.3 conveys the critical research needs identified by the participants in the East Coast and West Coast Workshops.

5.1 Standards

Participants in both workshops indicated that the workshops provided a good basis for beginning the process of developing ballast water treatment standards. Participants from each workshop were able to reach consensus on several issues. Many of these were similar between the workshops. Although no formal "voting" on specific statements was conducted at the East Coast workshop, the participants did reach agreement on several issues (Table 9). During the West Coast workshop, a formal "voting" on specific issues pertaining to the development of a ballast water standard was conducted. Table 10 presents a summary of the issues on which the West Coast participants reached consensus. The review of the consensus statements on Day 3 by the West Coast Workshop consolidated several previous consensus statements into a single statement and edited others. Specifically, a single statement was provided that consolidated the concepts of minimum and maximum protection into a goal of 100 percent protection from aquatic nonindigenous organisms and pathogens. The two consensus statements on capacity were consolidated into one statement that says capacity of the receiving waters is not applicable to the ballast water treatment standard. In addition, a statement that the standard be based on absolute values was added. There were some issues that remained unresolved with East Coast participants and some issues where several West Coast participants chose to remain neutral.

Neither the East Coast nor West Coast participants developed an approach to ballast water treatment standards that conformed, *per se*, with those suggested by the Ballast Water Shipping Committee. The participants from both workshops, however, discussed the BWSC options. Although the participants from both workshops generally agreed that Ballast Water Exchange was not an adequate approach to use for developing a standard, the East Coast workshop did not want to eliminate it from discussions. They did not necessarily think the standard should be based on ballast water exchange, but they were not opposed to the practice if it could be conducted with a high enough efficiency to achieve the standard.

Both the East Coast and West Coast participants deliberated over the question of whether a biologically-based ballast water treatment standard was feasible at this time. Participants from both workshops concluded that development of a biological standard was feasible at this time. They were able to draft language for both short-term and long-term ballast water treatment standards.

Table 9. Summary of East Coast Workshop Consensus Issues.

Issue	Consensus	Unresolved
Multiple standards may be necessary	X	
Multiple standards should be based on the three functional groups: 1) coastal holoplankton, meroplankton and demersals; 2) photosynthesizers including phytoplankton, cysts and algal propagules; and 3) bacteria, viruses, including pathogens	X	
The standard(s) should be biological, that is, one based on living organisms	X	
The standard(s) should not be based on capacity of receiving system	X	
The standard(s) should be a national standard(s) but with flexibility to address regional issues	X	
The standard(s) may be phased, relying on best available technology initially	X	
Both laboratory testing and shipboard testing are necessary	X	
Identifying indicator organisms is a necessity	X	
Identifying other surrogate indicators for shipboard testing would be very helpful	X	
Conditions used to test the standard should encompass a range of environmental conditions	X	
The standard(s) should be protective to reduce risk to the ecosystem, human health and the economy	X	
Ideally, a long-term standard should allow “zero” invasions from organisms in ballast water	X	
The standard(s) should be based on best available technology		X
Ballast water exchange should still be considered as treatment		X
How should the standard be applied to old and new ships?		X
What should the specific indicator or surrogate for each functional group?		X

Table 10. Summary of West Coast Workshop Consensus Issues.

Issue	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Ballast water exchange is not an adequate benchmark	**9**				
The standard should apply to all ballast water discharge regardless of port of origin	**7**	**2**			
A national standard should be set	**6**	**3**			
The standard should protect against future invasions of nonindigenous organisms and also protect against discharge of pathogenic organisms	**7**	**1**	**1**		
At this time, the capacity of the receiving system is not applicable to this standard	**7**	**1**	**1**		
The standard should provide for no detectable release of nonindigenous organisms and pathogens	**5**	**4**			
The standard will be based on absolute values	**4**	**5**			
The goal of the standard is to provide 100 percent protection from aquatic nonindigenous organisms and pathogens	**5**	**3**	**1**		
SHORT-TERM STANDARD Discharge should not include organisms greater than 50 µm and should be treated to meet fecal coliform standards (federal criteria for water contact recreation)	**6**	**3**			

The East Coast participants drafted three short-term standards statements and three long-term standards. These were based on three different functional groups identified during their discussions: 1) coastal holoplankton, meroplankton and demersals; 2) the photosynthesizers which consist of phytoplankton, cysts, and algal propagules; and 3) bacteria and viruses, including pathogens. The short-term standards identified by the East Coast participants were:

- 99 percent removal of all coastal holoplankton, meroplankton, and demersals, and their respective life stages.
- 95 percent removal or inactivation of all phytoplankton, cysts, and algal propagules and their respective life stages.
- *Enterococci* in ballast water discharge should not exceed 35/100 mL or *E. coli* should not exceed 126/100 mL.

The long-term standards developed by the East Coast participants were similar for two of the three functional groups (i.e., coastal holoplankton, meroplankton, demersals group and the photosynthesizer functional group) in that both groups recommended that all of these organisms and their respective life stages should be removed or rendered inactive. The long-term standard for the bacteria/virus/pathogen functional group was identical to the short-term standard and set a limit based on present bacterial indicator criteria for marine waters.

The West Coast participants did not develop standards specific to any functional group. The West Coast participants were also uncomfortable recommending a standard that provided less than 100 percent protection and felt strongly that the only acceptable standard was "zero discharge of viable organisms." Through their deliberations, the West Coast participants were able to come to consensus on the following short-term standard:

> Discharge should not include organisms greater than 50 μm and should be treated to meet federal criteria for contact recreation (35 Enterococci/100 mL for marine waters and 126 E. coli/100 mL for freshwater).

The West Coast participants agreed that the long-term standard should be zero discharge of organisms.

5.2 Protocols

While no definitive testing design protocols for verification of a ballast water standard(s) were developed during either workshop, a number of issues related to protocols were identified. Participants generally agreed that testing of any specific treatment technology's capability to meet the standard should be conducted at different scales including both laboratory and shipboard testing. Testing across a range of environmental conditions including such parameters as salinity, temperature, pH, and turbidity was also recommended. In addition to small- and large-scale testing, the operation and maintenance of the treatment systems were identified as factors to be included in testing protocols. Overall, participants felt that a substantial amount of research is still needed with regard to testing protocols, particularly in the area of surrogate organisms and methods for sampling and measuring organism viability in ballast tanks.

5.3 Research Needs

A key component of each workshop was identification of research that would aid in the development of a ballast water treatment standard. Many participants reiterated that although there has been a large amount of recent research and attention focused on the issues of invasion biology, there are still many unknowns in the field, particularly with respect to ballast water. Many questions remain regarding the invasion potential of different taxa, and these were identified as unanswerable with the present knowledge. The ability to predict *a priori* the invasion potential was also considered problematic and a major unknown. The need for information on the ecological, economic and human health risk of previous invasions, as well as a scientifically defensible approach that will allow for the evaluation of risk of invasion under various environmental conditions, was a research theme clearly articulated by both workshops. Additionally, development of a statistical protocol to define a standard for no potential for invasions (i.e., what is "zero") must be identified based on the accuracy and precision of the analysis.

The research needs identified by the participants can be categorized on a non-priority basis into five groups:

1) Biology of ballast tanks
2) Risk/likelihood of invasion
3) Identification of indicator species and/or surrogates
4) Efficacy of treatment technologies
5) Methodologies and protocols

Biology of ballast tanks. Many participants felt that basic research on the biology of ballast tanks is necessary. To assist in developing ballast water treatment standards, crucial information recommended relative to the biology of ballast tanks included:

- Life cycle dynamics of organisms in tanks,
- Survivability of organisms in ballast tanks overall
- Survivability of organisms in ballast tanks on various shipping routes
- Sediments in ballast tanks and the influence of sediment resuspension on biology within tanks
- Mixing within ballast tanks and its impact on the biology within the tanks
- Biology of organisms living within the sediments (i.e. cysts) Can cysts form from a bloom in a tank over the time frame typical of ballasting? Are cysts formed from blooms in the tank a problem, or is it the cysts in the sediments drawn in with ballast water that are problems? Do cysts in sediments become resuspended during transit?

Risk/likelihood of invasion. Although participants agreed that the ability to predict the likelihood of invasion may never be known, additional research on invasion biology and methods to assess potential risk of invasion were considered essential. This information gaps include:

- Invasion rates of different organisms
- How organisms discharged into a system become established
- Better knowledge of individual receiving systems
- Quantitative and/or statistical protocols to estimate risk.

Identification of indicator species and/or surrogates. All participants agreed that one of the most critical research questions is the identification of appropriate species indicators that can be used as indicators and/or those that can serve as surrogates. Recommended information included:

- How easily detected and measured is the indicator or surrogate?
- What is the removal behavior of the indicator or surrogate compared to the different classes of organisms that must be removed?
- The applicability of potential indicators such as ATP and chlorophyll.
- The reliability of an indicator such as chlorophyll or ATP on phytoplankton (or other species) viability after treatment.
- The degradation kinetics of organisms under different environmental conditions following treatment.

Efficacy of treatment technologies. Participants agreed that more information is necessary regarding the efficacy of treatment technologies including:

- What treatment technologies currently exist?
- How effective are those various treatment technologies on a range of taxa/functional groups under various environmental conditions, as well as flow rates and mixing regimes?
- Additional performance data for all available technologies at both small and large scale – including shipboard testing.
- How water quality factors influence treatment effectiveness or test organisms.
- Additional information on ballast water exchange and mechanisms to make this technology more effective.
- Impact of ship architecture and age on the efficacy of various treatment technologies.
- How well will the various technologies function over the operational life span of the equipment?

Methodologies and protocols. Participants supported the need to identify and develop methodologies and protocols that will be used to determine if various treatment technologies perform to specifications (i.e., do what they say they will do). Identified research needs included:

- How to detect the viability of organisms in ballast tanks.
- Development of instrumentation to detect viability and/or to sample ballast tanks.
- Additional information of standardized mortality assays (i.e., viability assays) for a range of taxa/functional groups.
- Additional information on bioassays using various treatment concentrations and time periods for a range of taxa/functional groups.

APPENDIX A

Contents of the Workshop Briefing Package

Ballast Water Treatment Standards Workshop

Briefing Package

Table of Contents

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SECTION 5 STANDARDS DEVELOPMENT

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SECTION 7 LOGISTICS

Hotel Information

- Directions
- Area Restaurants
- Invoice Form

APPENDIX B

List of Participants and Observers

Ballast Water Treatment Standards Workshop

AmeriSuites Hotel
Mystic, Connecticut
April 17-19, 2001

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Ballast Water Treatment Standards Workshop

Best Western Inn at the Square
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May 23-25, 2001

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Ballast Water Treatment Standards Workshop

East Coast and West Coast Workshops

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Ballast Water Treatment Standards Workshop

East Coast and West Coast Workshops

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